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Silage or Limit-Fed Grain Growing Diets for Steers: I. Growth and Carcass Quality[1]

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ABSTRACT: The influence of energy source (silage- [S] or grain- [G] based) on organ growth, carcass quality, and meat acceptability independent of rate of gain was examined. Sixty-four Angus steers were allotted to one of the two treatments and given ad libitum access to silage or limit-fed grain for 145 d. All steers were then given ad libitum access to a grain diet for 45, 75, or 105 d. Eight steers from each treatment were slaughtered at the end of the growing phase and at each of the termination dates. The silage-based growing diet consisted (DM basis) of 55% sorghum silage (averaged 23.6% dry matter), 22% alfalfa hay, 10.8% ground shelled corn, and 10.8% soybean meal and contained 12.8% CP. Dry matter in the grain-based diet, composed of 76.5% ground shelled corn, 5% soybean meal, 13.6% cottonseed hulls, 3.5% molasses, and .4% salt and 1% limestone, contained 12.1% CP. It was limit-fed to produce rates of gain similar to the silage diet eaten ad libitum, using net energy for gain of each diet calculated from organic matter digestibility determined in digestion trials. The finishing diet was similar to the grain growing diet except that alfalfa hay replaced the cottonseed hulls. No implants or ionophores were used. High silage moisture decreased ADG the first 45 d, so steers fed grain gained faster, but thereafter gains were similar. At the end of the growing phase, steers fed grain had heavier shrunk and empty body weights and larger livers. However, liver size was not different when adjusted for growing ADG. By 45 d with ad libitum access to the finishing diet, 75% of the carcasses from steers fed both diets graded Choice. Steers fed silage had tougher ($P < .05$) steaks with less flavor intensity ($P < .05$) at the end of the growing phase; these differences diminished after 75 d on feed. These results suggest that Choice beef can be produced in only 45 d in the feedlot, but tenderness and flavor among Choice carcasses remained inferior for steers fed silage for at least 75 d on a high-grain diet.

Key Words: Beef, Forage, Concentrates, Carcass Quality, Tenderness

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Introduction

Various economic, ecological, and world food events have increased the interest in using larger quantities of forage and less grain in beef production. Consumer interests in leaner beef have refueled the interest in feeding cellulosic feeds, which often reduced both rate and fat content of gain (Byers, 1982; Rompala et al., 1984). Schroeder et al. (1980) observed that carcasses of cattle fed forage had lower quality grades and overall desirability than cattle subsequently fed grain. However, cattle fed grain were older and larger. Utley et al. (1975) fed yearling steers to the same final live weight on either grain or forages and detected no differences in carcass grade or marbling score; in contrast, when calves rather than yearlings were used, those fed all-forage diets had lower marbling and carcass scores. Smith et al. (1977) found that meat palatability was lower for steers

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slaughtered directly off grass compared to steers fed grain, but this difference disappeared after 49 d of feeding grain. Other problems with beef cattle finished on forage include yellow fat and dark meat; however, steers produced whiter fat when fed grass than when fed silage or grain (Smith et al., 1977). This research was initiated to determine whether source of nutrients during the growing phase influenced carcass quality and meat acceptability. A second objective was to characterize changes in these factors with duration of time during a finishing phase.

Experimental Procedure

The experiment consisted of two phases: 1) a 145-d growing phase in which either silage- or grain-based diets (Table 1) were fed to produce the same rate of gain and 2) a 105-d finishing phase to determine the influence of diet in the growing phase on subsequent growth and carcass quality. One hundred twenty Angus steers, predominantly medium-framed, were obtained from a single source. Sixty-four steers were selected from the larger group, blocked according to weight, and assigned randomly within blocks to one of the two dietary treatments. These 64 steers were then placed in a feeding barn equipped with Calan headgates (American Calan, Northwood, NH)[4] to facilitate measuring individual intake and trained while eating a diet of 55% corn and 45% cottonseed hulls. Sixteen pens of four steers per pen were used.

All steers were fed once daily; orts were collected and weighed weekly. Samples of the silage before and after addition of supplement were taken each day and the grain diet was sampled each week. Samples of feed and orts were collected, dried at 65°C for 3 d, and subsequently dried at 135°C for 2 h before the dry weight was recorded. This sample was used to calculate dry matter intake. Each week, average intake of silage was determined as a proportion of metabolic weight ($WT^{.75}$). Net energy for gain (NE_g) intake was calculated from organic matter digestibility determined in digestion trials and rate of gain projected for the steers fed silage using equations by NRC (1984). The amount of grain diet required for similar gain was then calculated, also using organic matter digestibility determined on the diets and equations from NRC (1984).

Diet Characterization. A group of the remaining steers was used to characterize the diets in two digestion and metabolism trials, one to characterize the growing diets and another to characterize the finishing diet. In metabolism trial one, five steers were assigned randomly to each diet (phase 1) and housed in conventional stalls for separate collection of feces and urine. A 10-d adaptation period was followed by total collection of feces and urine on d 11 through 15. In metabolism trial two, eight steers were fed the finishing diet under the same conditions as above. Procedures were described by Coleman and Evans (1986).

Daily aliquots of the silage samples and orts were obtained and dried at 65°C, composited, ground, and subsampled for analysis. Daily samples of the grain diets were composited. Feces were weighed daily and a 5% aliquot was composited with thymol to prevent mold formation and stored at 4°C. Immediately following the trial, composite fecal collections were mixed thoroughly, and a subsample was dried at 65°C and ground for analysis. Urine was collected under HCl, diluted to 10 L each day, and 100 mL was stored at 4°C for later analysis. Dried feed, feces, and ort samples were analyzed for dry matter (DM), organic matter (OM), and crude protein (AOAC, 1980) and for neutral detergent fiber (NDF; Van Soest and Wine, 1967). Urine samples were analyzed for nitrogen (AOAC, 1980). Digestion coefficients were calculated for DM, OM, crude protein, and NDF. Digestible OM was calculated and assumed to equal total digestible nutrients for the purpose of calculating digestible, metabolizable, and net energy using equations from NRC (1984).

Slaughter and Carcass Evaluation. Initially, at the completion of the growing phase and again at 45, 75, and 105 d of the finishing phase, eight steers per treatment were slaughtered at the abattoir at Oklahoma State University. Steers for the initial slaughter group were selected at random from the original 120 steers at the same time the 64 experimental steers were selected. On subsequent slaughter dates except the initial, one steer was selected randomly from each of the 16 pens with the restriction that an overlapping

Table 1. Composition of diets fed during growing and finishing phases

Item	Growing: Silage	Growing: Grain	Finishing
	% Dry matter		
Sorghum silage[a]	55.0	—	—
Ground shelled corn	10.8	76.5	73.1
Soybean meal	10.8	5.0	9.0
Cottonseed hulls	—	13.6	—
Alfalfa hay[a]	22.0	—	12.8
Cane molasses	—	3.5	3.5
Salt	.3	.4	.6
Limestone	.3	1.0	1.0

[a]Alfalfa hay was added after 45 d when a different silage pit was opened in which the silage dry matter content was 23%.

[4]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

Table 2. Chemical composition and component digestibility of diets

Item	Growing		
	Silage[a]	Grain	Finishing
Chemical analysis, %			
Dry matter[b]	34.6	85.7	84.4
Organic matter	91.0	95.2	94.3
Crude protein	12.8	12.1	13.0
NDF[c]	59.1	38.4	29.6
Digestion coefficients, %[d]			
Dry matter	60.2 ± .76	79.4 ± 1.92	78.7 ± .86
Crude protein	58.1 ± .39	68.8 ± 2.99	66.8 ± 1.12
NDF	55.2 ± 1.41	64.4 ± 3.79	64.2 ± 1.85
Digestible OM[e]	56.0 ± 1.64	76.6 ± 1.81	75.0 ± .81
N retained, g/d	38.5 ± 3.73	18.5 ± 2.39	46.0 ± 5.15
N retained, %			
Of consumed	11.5 ± .73	8.4 ± .86	12.0 ± 1.35
Of digested	54.0 ± 2.58	38.0 ± 4.74	55.3 ± 4.08
Calculated energy, Mcal/kg[f]			
Digestible	2.472	3.382	3.311
Metabolizable	2.027	2.773	2.715
Net for maintenance	1.178	1.842	1.792
Net for gain	.615	1.210	1.167

[a]Silage with 10% hay, 5% corn, and 5% soy meal.
[b]As-fed basis. Other constituents on a dry matter basis.
[c]Neutral detergent fiber.
[d]Digestion coefficients based on average of five steers/diet for growing phase and eight steers for finishing diet.
[e]Digestible organic matter = organic matter digestibility × % dietary OM.
[f]Energy based on NRC (1984) equations assuming TDN = digestible OM determined from digestion trials.

range of weights across diets were included at each slaughter date.

Two days before the scheduled slaughter at approximately 1600, steers were moved from their pens to a location without feed and water. They were weighed at 0700 the next morning and returned as a group to a pen with hay and water. They were transported from El Reno to Stillwater (150 km) at approximately 0600 the following day, weighed upon arrival, stunned with a captive-bolt gun, and exsanguinated. Weights of blood, hide, head, feet, visceral organs, full and empty digestive tract, rumen and mesenteric fat, and warm carcasses were obtained.

After a 24-h chill at 2°C following slaughter, carcasses were evaluated (USDA, 1976). Longissimus muscle area and backfat thickness were measured directly. The 9-10-11th rib section was removed from one side of each carcass; opposite sides were selected on each subsequent slaughter date. The rib sections were kept at 2°C for a total chill period of 7 d, after which they were packaged and stored at −32°C until they were analyzed. All rib sections were shipped to the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE under Dry Ice for sensory and shear evaluations. The procedures followed those described by Crouse et al. (1989). Two 2.5-cm-thick steaks from each carcass were used for sensory evaluation and one was used for shear measurement. They were thawed approximately 24 h in the refrigerator (2 to 5°C) and cooked on open hearth electric broilers.

Steaks for shear force evaluation were scored for color after removal from the broiler and cooled at 2 to 5°C for 3 h and six cores were used for measurement. Steaks for sensory evaluations were wrapped in foil and held in a convection oven at 70°C. Cooking was staggered so that holding time was less than 30 min. Samples (three cubes) were scored by a trained seven-member descriptive attribute panel. Statistical analyses were conducted using the mean score from the seven panelist scores.

Statistical Analyses. All weights, weight gains, feed intake, and efficiencies were analyzed by the following model: $Y_{ijk} = Diet_i + Pen_j(Diet) + SLGR_k + Diet \times SLGR + e_{ijk}$, where Y_{ijk} = dependent variable of weight, growth rate, feed consumption, and efficiency; Diet = i^{th} diet; Pen(Diet) = j^{th} pen within diet and the error term for diet; SLGR = k^{th} slaughter group, representing different times in the feedlot; Diet × SLGR = interaction of diet and slaughter group; and e_{ijk} = random error. Organ weights, carcass traits, and carcass quality attributes were analyzed using the following statistical model: $Y_{ij} = IWt + GADG + Days + Days^2 + GADG \times Days + GADG \times Days^2 + Diet_i + Days \times Diet_i + Days^2 \times Diet_i + e_{ij}$, where Y_{ij} = dependent variable of empty body components and chemical composition; IWt = empty body weight at initiation of the experiment; GADG = daily empty body gain during

Table 3. Growth rate and feed conversion during the growing phase for steers fed silage or grain growing diets

Growing phase	Growing diet: Silage	Growing diet: Grain	Significance[a]: Diet	Significance[a]: SLGR	Significance[a]: D × S
Initial shrunk wt, kg	259.5 ± 4.34	259.9 ± 3.96			
Initial EB wt, kg	226.5 ± 3.57	226.8 ± 3.25			
Final shrunk wt, kg	343.2 ± 6.08	369.7 ± 5.34	**		
Final EB wt, kg	281.4 ± 4.99	318.0 ± 4.59	**		
GIT fill, kg	61.8 ± 1.09	51.8 ± .75	**		
Daily gain, kg	.582 ± .025	.763 ± .026	**		
Daily EB gain, kg	.382 ± .020	.633 ± .022	**		
DM intake, kg/d	6.62 ± .122	4.89 ± .059	**	*	
ME intake, Mcal/d	13.4 ± .248	13.6 ± .165		†	
NE_g, Mcal/d	4.08 ± .075	5.92 ± .072	**	†	
Feed/gain, kg/kg EB	19.5 ± 1.54	8.00 ± .284	**		†
ME/gain, Mcal/kg EB	39.5 ± 3.13	22.2 ± .785	**		†
NE_g/gain, Mcal/kg EB	12.0 ± .95	9.68 ± .350	*		†

[a]SLGR = slaughter group 1–4 corresponding to 0, 45, 75, and 105 d on feed. D × S = diet × slaughter group interaction.
†$P < .10$.
*$P < .05$.
**$P < .01$.

Table 4. Growth rate and feed conversion during the finishing phase for steers previously fed forage or concentrate growing diets

Finishing phase	Growing diet: Silage	Growing diet: Grain	Significance[a]: Diet	Significance[a]: SLGR	Significance[a]: D × S
Final shrunk wt, kg			*	**	
0 Days	342.8 ± 12.2	369.0 ± 9.89			
45 Days	399.7 ± 10.8	424.1 ± 14.1			
75 Days	426.5 ± 12.0	438.9 ± 10.1			
105 Days	447.7 ± 19.0	457.2 ± 10.0			
Final EB wt, kg			*	**	
0 Days	281.1 ± 9.97	317.3 ± 8.50			
45 Days	352.3 ± 8.34	373.2 ± 12.4			
75 Days	379.1 ± 9.37	397.9 ± 9.75			
105 Days	409.0 ± 15.4	419.4 ± 8.92			
Daily gain, kg	1.01 ± .047	.92 ± .040			
Daily EB gain, kg			**	†	
45 Days	1.34 ± .081	1.10 ± .085			
75 Days	1.23 ± .081	1.00 ± .060			
105 Days	1.20 ± .072	.94 ± .049			
DM intake, kg/d	9.01 ± .172	7.51 ± .217	**		
NE_g, Mcal/d	10.51 ± .203	8.76 ± .253	**		
Feed DM/EB gain, kg/kg				*	
45 Days	6.70 ± .354	6.84 ± .509			
75 Days	7.21 ± .382	8.10 ± .463			
105 Days	8.07 ± .302	7.73 ± .314			
NE_g/EB gain, Mcal/kg				*	
45 Days	7.82 ± .414	7.98 ± .594			
75 Days	8.41 ± .442	9.46 ± .537			
105 Days	9.42 ± .355	9.03 ± .363			

[a]SLGR = slaughter group 1–4 corresponding to 0, 45, 75, and 105 d on feed. D × S = diet × slaughter group interaction.
†$P < .10$.
*$P < .05$.
**$P < .01$.

the growing phase; Days = days from the end of the growing phase until slaughter; $Diet_i$ = i^{th} growing diet of either silage or grain; GADG × Days, GADG × $Days^2$, Days × Diet and $Days^2$ × Diet the appropriate interactions; and e_{ij} = random error. When $Days^2$ or its interaction were not significant ($P > .10$), it was dropped from the model. The GLM procedure of SAS (1990) was used for all analyses.

Results

The digestion coefficients and calculated energy content of the diets are presented in Table 2. Digestibility values for dry matter and organic matter are typical, except that digestibility of the grain diets (both growing and finishing) were slightly below those expected. Nitrogen digestibility was adequate, but nitrogen retention was lower for steers fed the grain diet than for those fed the silage diet. This probably was due to reduced dietary N intake for the grain diet, even though crude protein content was similar. With intake restriction, a higher protein percentage is needed to maintain equal protein intake. Retained N as a percentage of consumed and digested N reflects the proportion of endogenous urinary N to total N absorbed. All steers were in positive N balance. However, the lower N retention suggests that steers limit-fed grain were probably deficient in protein.

The grain-based growing diet furnished almost twice as much NE_g/kg as the silage-based diet. The slight changes (substitution of hay for cottonseed hulls) made in the finishing diet resulted in a slightly lower NE_g than in the grain diet fed during the growing phase. Because these values were calculated from digestible organic matter, perhaps greater intake of the finishing diet reduced nutrient digestibility.

Growth Rate. One steer from each treatment died of bloat during the finishing phase. Hence, the final slaughter group had only seven steers per dietary treatment. Weights, intake, and rate of gain for the growing phase as influenced by diet are shown in Table 3. Patterns of weight, ADG, and silage DM percentage over the growing phase are shown in Figure 1. Our intent was to provide the steers equal NE_g intake; however, differences ($P < .01$) in intake, and subsequently in rate of gain (Figure 1, top and middle panel), occurred between diets early in the trial and persisted, as reflected by ADG throughout the growing phase (Table 3). At about 30 d into the trial, steers fed silage reduced their consumption of the diet, presumably because of high moisture content of the silage (Figure 1, bottom panel). The lag time in reducing the supply of feed for steers fed grain resulted in faster ADG for that period. However, after 10% dry hay was added to the silage diet, intake increased and ADG reflected our projections. A short

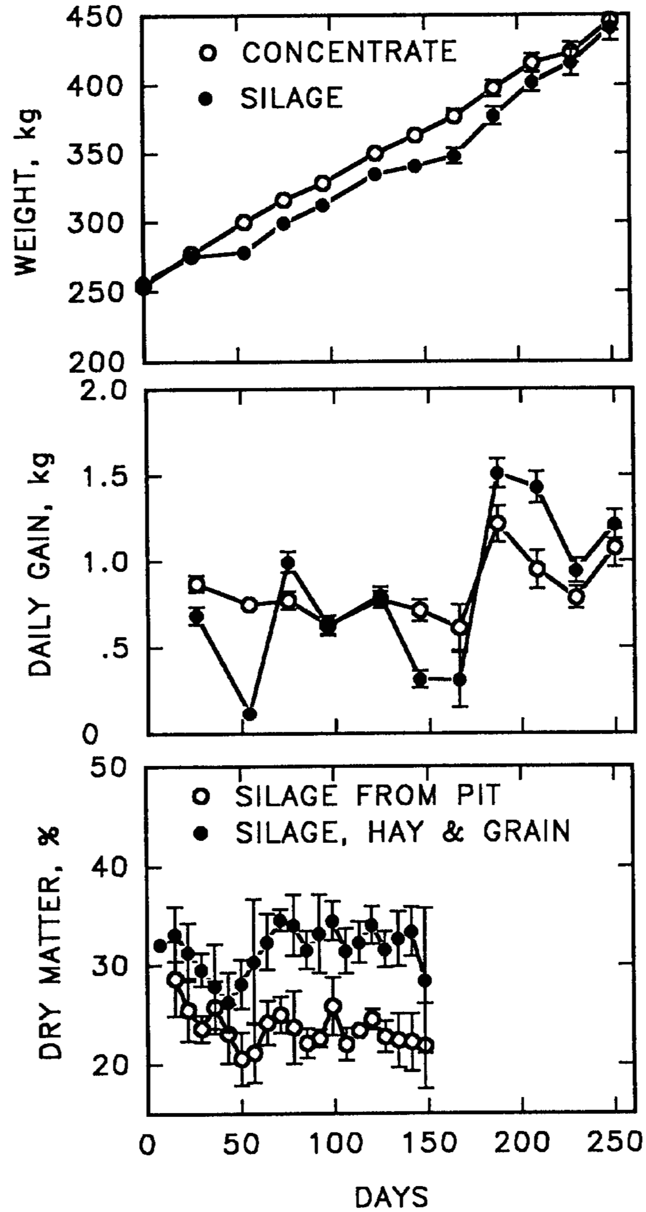

Figure 1. Weights (top panel), daily gain (middle panel), and silage dry matter percentage (bottom panel) over days during both growing and finishing phase. The growing phase terminated at 145 d.

compensatory gain (probably gut fill) was evident during the next period; thereafter, gains for both groups were similar until the end of the growing phase. To compensate for the potential effect of different rates of gain between treatments on empty body composition, steers were selected at each slaughter date to provide a wide and overlapping slaughter weight that should be indicative of rate of gain.

Gastrointestinal tract fill was calculated for all steers at the end of the growing phase using empty

Table 5. Organ weights of steers as affected by silage (S) or grain (G) diet, days on feed, and rate of gain during the growing phase

Organ and diet	Init[b]	Days on feed: 0	45	75	105	Regression coefficients[a]: Int[c]	GADG[d]	DaysL[e]	DaysQ[e]	G × D[f]	G × D²	SD[g]
		kg										
Blood												
S	8.64	8.3	11.5	10.7	11.2	11.6	-4.91	-.016	—	.066	—	1.61
G		9.2	10.6	10.8	11.8	11.6	-4.91	-.016	—	.066	—	
Head												
S	9.62	10.4	11.8	11.6	13.1	10.8	-.21	-.075	.0007*	.118†	-.0009	.70
G		10.8	11.7	11.7	12.9	10.8	-.21	-.075	.0007*	.118†	-.0009	
Hide												
S	20.46	25.5	29.7	31.4	31.9	17.4	5.13	.044	—	.025	—	2.31
G		27.2	31.8	31.1	32.6	17.4	5.13	.044	—	.025	—	
Liver												
S	3.85	3.95	5.61	5.96	5.90	2.12	4.07*	.101**	-.0007*	-.101	.0007*	.61
G		4.48	5.54	5.55	6.14	2.12	4.07*	.101**	-.0007*	-.101	.0007*	
Rumen												
S	9.68	11.8	14.4	16.3	17.0	7.59	9.38*	.097**	—	-.072	—	1.71
G		12.7	15.1	17.2	16.6	7.59	9.38*	.097**	—	-.072	—	
Intestine												
S	7.40	9.1	10.5	11.0	11.8	10.1	-1.14	.027	—	.007	—	1.36
G		10.3	10.6	10.2	12.5	10.1	-1.14	.027	—	.007	—	
Bone												
S	12.92	17.5	19.7	20.5	18.4	16.2	3.59	.015	.0002	.046	-.0004	.83
G		18.6	20.0	20.9	23.1	16.2	3.59	-.025	.0006	.046	-.0004	
Fat[h]												
S	4.37	5.6	9.6	11.2	14.2	3.57	6.43	.059*	—	.051	—	1.94
G		7.8	12.1	12.5	13.9	3.57	6.43	.039*	—	.051	—	

[a]Initial empty body weight was included for adjustment as a covariate. Different intercepts for silage and grain diets indicate significant average diet effects. Different coefficients for days indicate significant dynamic effect.
[b]INIT = initial slaughter group.
[c]INT = intercept, which is effect of diet at d 0. Different intercepts for S and G diets indicate significant diet effect.
[d]GADG = rate of empty body gain during the growing phase.
[e]DaysL = linear effect of days on feed; DaysQ = quadratic effect of days on feed.
[f]G × D = interaction of GADG and days on feed; G × D² = interaction of GADG and quadratic effect of days on feed.
[g]SD = residual standard deviation for the model.
[h]Internal fat trimmed from rumen and gastrointestinal tract.
†Regression significant ($P < .10$).
*Regression significant ($P < .05$).
**Regression significant ($P < .01$).

body (**EB**) weight calculated from the regression of EB vs body weight (zero-intercept) based on steers slaughtered at that time. These equations were: EBWT = .82 × live weight (R^2 = .96) for silage diets and EBWT = .86 × live weight (R^2 = .94) for grain diets. Steers fed silage had about 10 kg more fill than grain-fed steers, further exacerbating the difference in final EB weight and rate of EB gain. Empty body gain of steers fed grain was almost twice that of steers fed silage (P < .01).

Despite the fact that steers fed silage consumed more feed dry matter (P < .01), they consumed similar (P > .05) amounts of metabolizable energy (ME) and less (P < .01) NE_g than steers limit-fed the grain diet. There also were differences in intake of DM (P < .05), ME (P < .10), and NE_g (P < .10) for steers assigned to the different slaughter groups. Steers in the first two groups ate more feed (5.92 vs 5.60 kg DM/d) than steers in the latter two groups (data not shown). Feed dry matter and ME required for EB body weight gain was lower (P < .01) for the grain- than for the forage-based diet, as was expected. Unexpectedly, however, grain-fed steers were more efficient (P < .05) in converting NE_g to EB gain. Whether this is due to sampling, especially of the silage, or to our method of calculating NE_g from digestibility cannot be ascertained.

During the finishing phase, steers previously fed the grain diet were heavier (P < .05), a trend that held for each slaughter date (Table 4). This difference primarily was a function of weight at the end of the growing phase; no differences (P > .10) in daily gain were noted during the finishing phase. However, daily EB gain was higher (P < .01) for steers fed silage. Also, steers previously fed silage consumed more dry matter and NE_g than steers that were previously fed the grain diet at restricted intake. This likely was due to greater rumen capacity of forage-fed steers, especially early in the finishing phase. Efficiency of conversion of feed dry matter or NE_g to EB gain decreased (P < .05) with progressive slaughter groups, indicating loss in efficiency as steers grew larger and more mature.

Organ Weights. Because we were not able to control NE_g intake and weight gain precisely during the growing phase, daily empty body gain during the growing phase (**GADG**) was included in the statistical model as a covariate. Initial empty body weight was included to account for non-random assignment to diets and to slaughter groups, but these coefficients are not presented or discussed. Linear and quadratic effects of days in the feedlot were used to determine the dynamic accumulation of tissue types. The inclusion of interactions of GADG with days in the feedlot was an attempt to account for the expected decline in the influence of events during the growing phase. Diet and its interaction with days accounted for the effects of diet at the beginning of the finishing phase (differences in intercept) and for the dynamic effect of diet on changes with time on feed (differences in slope or regression coefficient).

In Table 5, for instance, if the intercepts for different diets were the same, then there was no diet effect at the end of the growing phase, as was the case for all organs. If the coefficients for linear (Days L) and quadratic (Days Q) were different for diets, then the rate of change during the finishing phase was different for steers fed grain or silage during the growing phase. It is possible that the overall effect of days was not significant because of the interaction with diet. Bone weight is a good example, because the linear coefficients were positive for silage-fed steers and negative for grain-fed steers. The negative slope for grain-fed steers was compensated for by a large positive quadratic coefficient.

Although slight numerical differences due to diet were noted in the mean weights of several organs (Table 5), especially at the end of the growing phase (0 d), these may be explained by differences in EB weight. In a separate analysis (data not shown), diet effects were not significant for organ weights expressed as a proportion of EB weight. Regression analysis revealed similar results; no differences (P > .10) due to diet were noted in intercepts for any organs. The regression coefficient for days represents growth rate for each organ. These were similar for diets, except for bone and internal fat. Any observed differences in means of other organs were accounted for by adjustments in GADG or initial weight. The increase in mass of blood, head, hide, intestinal mass, or bone beyond the growing phase was minor. However, significant (P < .05) positive regression coefficients were detected for liver (quadratic), rumen (linear), and internal fat (linear). Using the derivative of the regression equation, liver size reached a maximum at about 64 d, which agrees with visual observations of the means. Rumen weight continued to increase at 92 g/d, although there was indication of a plateau of 17 kg for steers fed grain during the growing phase.

Carcass Attributes. Carcass characteristics are presented in Table 6. Intercepts for the two diets differed (P < .10) for dressing percentage, longissimus area, and quality grade. Differences in intercept are indicative of differences at the end of the growing phase. In general, steers fed silage entered the feedlot with lower dressing percentage, smaller longissimus area, and lower carcass quality grade. Significant effects of GADG were noted for carcass weight, longissimus area, and yield grade. Interactions (P < .10) of the linear effect of days on feed and diet were observed for all dependent variables except for KPH and yield grade. Steers fed silage produced more rapid increases in weight, dressing percentage, backfat thickness, marbling score, and quality grade. A negative quadratic effect was noted for marbling score

Table 6. Influence of silage (S) or grain (G) diet, days on feed, and rate of gain during the growing phase on carcass characteristics[a]

Item and diet	Init[c]	Days on feed 0	45	75	105	Regression coefficients[b] Int[d]	GADG[e]	DaysL[f]	DaysQ[f]	G × D[g]	G × D[2]	SD[h]
Weight, kg[i]												
S	151	183	236	254	280	146.0	102.7**	.933**	—	.101	—	10.7
G		213	250	273	285	146.0	102.7**	.671**	—	.101	—	
Dressing percentage												
S	56.7	57.8	61.9	62.3	64.1	56.7	3.62	.052*	—	.018	—	1.58
G		61.1	62.7	64.4	63.9	59.2	3.62	.015	—	.018	—	
Backfat, mm[j]												
S	1.97	4.19	7.24	9.91	10.74	3.24	4.00	.021	—	.095†	—	2.04
G		6.73	7.24	10.16	9.72	3.24	4.00	−.039	—	.095†	—	
Kidney, pelvic and heart, %[k]												
S	1.13	1.66	1.62	1.56	1.96	.726	1.79	.0010	—	.002	—	.455
G		1.94	1.56	1.87	2.07	.726	1.79	.0010	—	.002	—	
Longissimus area, cm^2												
S	54.7	59.3	69.0	69.5	73.4	76.2	−37.5*	−.655*	.0048†	1.35**	−.009*	5.66
G		66.5	75.1	74.8	72.1	89.4	−37.5*	−.783*	.0048†	1.35**	−.009*	
Marbling score[l]												
S	265	319	412	432	420	322.8	54.8	7.29*	−.070**	−7.66†	.091*	51.1
G		381	428	419	436	322.8	54.8	6.42*	−.070**	−7.66†	.091*	
USDA quality grade[m]												
S	269	321	398	404	400	335.1	19.5	4.02*	−.038**	−3.70	.048*	29.1
G		373	398	400	411	381.7	19.5	3.43*	−.038**	−3.70	.048*	
USDA yield grade												
S	1.54	1.96	2.31	2.56	2.78	.854	2.19*	.012†	—	−.007	—	.456
G		2.18	2.08	2.57	2.83	.854	2.19*	.012†	—	−.007	—	

[a]All were A maturity.
[b]Initial empty body weight was included for adjustment as a covariate. Different intercepts for silage and grain diets indicate they are different ($P < .10$). Different coefficients for days indicate different slopes ($P < .10$).
[c]INIT = initial slaughter group.
[d]Int = intercept, which is effect of diet at d 0. Different intercepts for S and G diets indicate significant diet effect.
[e]GADG = rate of empty body gain during the growing phase.
[g]G × D = interaction of GADG and days on feed; G × D^2 = interaction of GADG and the quadratic effect of days on feed.
[h]SD = residual standard deviation for the model.
[i]Chilled carcass weight.
[j]Measured backfat thickness without adjustment.
[k]Estimated kidney, pelvic and heart fat.
[l]Marbling score: 300 = slight; 400 = small; 500 abundant.
[m]Carcass grade: 300 = Select; 400 = Choice; 500 = Prime.
†Regression significant ($P < .10$).
*Regression significant ($P < .05$).
**Regression significant ($P < .01$).

Table 7. Sensory and shear evaluations of steaks as affected by silage (S) or grain (G) diet, slaughter group, and rate of gain during the growing phase

	Days on feed				Regression coefficients[a]						
Trait and diet	0	45	75	105	Int[b]	GADG[c]	DaysL[d]	DaysQ[d]	G × D[e]	G × D²	SD[f]
Sensory panel											
Juiciness[g]											
S	4.76	4.93	4.71	5.09	5.31	−.99	−.0025	—	.0098	—	.363
G	4.79	5.21	4.82	5.23	5.31	−.99	−.0025	—	.0098	—	
Beef flavor intensity[g]											
S	4.31	4.51	4.79	4.91	4.18	.246	.0039	—	.0001	—	.286
G	4.71	4.82	4.79	4.94	4.57	.246	.0039	—	.0001	—	
Off-flavor[h]											
S	2.61	2.70	2.90	2.95	2.51	.427	.0035	—	−.0027	—	.212
G	2.94	2.78	2.93	2.99	2.51	.427	.0035	—	−.0027	—	
Connective tissue[g]											
S	3.86	3.88	3.92	4.83	3.81	.231	−.022	.0002*	.0053	—	.894
G	4.86	4.61	3.87	4.84	4.79	.231	−.022	.0002*	.0053	—	
Ease of fragmentation[g]											
S	4.11	4.15	4.14	4.99	4.59	−.011	−.019	.0002*	.0032	—	.806
G	4.95	4.82	4.06	5.04	4.59	−.011	−.019	.0002*	.0032	—	
Tenderness[g]											
S	4.03	4.06	4.08	4.92	4.52	.047	−.019	.0002*	.0040	—	.823
G	4.92	4.73	4.02	4.95	4.52	.047	−.019	.0002*	.0040	—	
Shear force, kg[i]											
S	6.96	6.85	6.88	5.46	6.48	2.14	.0091	—	−.024	—	1.48
G	5.18	5.58	6.29	5.31	3.87	2.14	.0091	—	−.024	—	

[a]Initial empty body weight was included for adjustment as a covariate. Different intercepts for silage and grain diets indicate they are different ($P < .10$). Different coefficients for days indicate different slopes ($P < .10$).
[b]INT = intercept, which is effect of diet at d 0. Different intercepts for S and G diets indicate significant diet effect.
[c]GADG = rate of empty body gain during the growing phase.
[d]DaysL = linear effect of days on feed; DaysQ = quadratic effect of days on feed.
[e]G × D = interaction of GADG and days on feed; G × D² = interaction of GADG and quadratic effect of days on feed.
[f]SD = residual standard deviation for the model.
[g]1 = extremely dry, extremely bland, abundant, abundant, extremely difficult, extremely tough; 8 = extremely juicy, extremely intensive, void, none, extremely easy, extremely tender.
[h]1 = intense; 4 = none.
[i]Warner-Bratzler shear values (kg force).
*Regression significant ($P < .05$).

and quality grade, indicating a diminishing effect as time progressed. A negative linear coefficient for effect of days on feed on longissimus area reflects a reduction as the steers increased in size. However, the positive quadratic effect suggests longissimus area was increasing at an increasing rate at the end of the experiment. The interaction of days with GADG for both the linear and quadratic coefficient could influence both the sign and magnitude of these coefficients. This interaction also occurred for marbling score and quality grade.

Sensory and shear evaluations are presented in Table 7. Intercepts for beef flavor intensity, perceived connective tissue, and shear force were different ($P <$ .10), indicating that differences due to diet were detectable at the end of the growing phase. Basically, steers fed grain had greater flavor intensity, less off-flavor, and were more tender than steers fed silage. Perceived connective tissue, ease of fragmentation, and tenderness were altered quadratically by days on feed.

Discussion

Based on calculated ME and NE from digestible organic matter, the diets were as expected. Intake of ME was not different between the diets, similar to results reported by Smith et al. (1984), but intake of NE_g was higher for grain-fed growing steers in both experiments. Although this compromised our objective, variability in GADG within the treatments allowed us to adjust to a constant GADG for analysis of gain-dependent variables such as body composition and organ weights.

Fill was a significant factor in weight differences between the two diets at the end of the growing phase. Based on slaughter data, fill was 14% of final weight for steers fed grain and 18% of the final weight for steers fed silage. This 4 percentage difference accentuated the difference in rate of gain between the two diets and exemplifies the need to adjust or mitigate the effects of differences in fill when different diets are fed. Rohr and Daenicke (1984) noted that gut fill was 13% of live weight for cattle fed 85% grain diets and 17% for cattle fed an alfalfa hay diet. Reporting results on an empty body weight basis corrects for this bias. Waldo and Smith (1987) reported that gut fill was a quadratic function of dietary neutral detergent fiber.

Differential NE_g efficiency (Table 3) of forage- and grain-based diets was also reported by Vance et al. (1972). They found that whereas NE_m of dietary ingredients was consistent across a wide range of ratios of shelled corn to corn silage, NE_g was not consistent and depended on the level of the particular ingredient in the diet. When compared to calculated NE_g values, the determined NE_g was higher at both ends of the range of silage to grain; it equaled calculated NE_g only at 75% grain. Because their data were based on body composition of serially slaughtered cattle, they support the contention that utilization of NE_g is variable and depends on its source.

Organ weights were not influenced by diet during the growing phase (Table 5) after adjusting to a constant GADG. In both models, interactions occurred between days on feed and rate of gain during the growing period. Liver size seems to be related to intake of NE_g rather than source of energy. Intake of NE_g by steers fed grain was 50% greater than that by steers fed silage during the growing phase but 15 to 20% less during the finishing phase. Also, except for the liver, rumen, and fat, organ weights had apparently reached a plateau by the initiation of the finishing phase, as indicated by insignificant ($P > .10$) regression coefficients for days on feed. However, these coefficients were related to other independent variables in the statistical model, such as GADG.

Drouillard et al. (1991) showed that lambs restricted in energy intake had smaller livers and stomachs after 14 and 42 d than unrestricted lambs and indicated that energy intake influenced the size of these organs. Harmon et al. (1991) found that O_2 consumption of ruminal epithelial tissue was similar for calves fed forage or grain diets, but tissue from calves fed at twice maintenance had greater O_2 consumption than those fed at maintenance. Reynolds et al. (1990) found that gut and liver accounted for 44% and 72% of the whole-body heat increment for 75% grain and 75% forage diets, respectively. This accounted for 72% of the difference in tissue energy retention between silage- or grain-based diets fed at equal metabolizable energy. However, at equal ME intake, NE_g was higher for heifers fed grain. Ferrell (C. L., personal communication) noted that gut and liver energy expenditure increased as dry matter and net energy intake increased due to supplementation of a forage diet, but expenditure was not as great as from a grain diet. He further stated that liver and gut energy expenditures were increased by increases of both energy and fiber intake. The liver and gut used about 70% of the digestible energy intake in cattle fed poor-quality forage vs only 20% in cattle fed grain diets. This difference was due primarily to the proportion of net energy for gain to digestible energy in the respective diets.

Dressing percentage, longissimus area, and quality grade had different ($P < .10$) intercepts due to diet, even after adjustment for GADG (Table 6). These reflect observed differences in means at the end of the growing phase and were characterized by higher dressing percentage, marbling score, and carcass quality grade for steers fed grain. Longissimus area, marbling score, and quality grade were influenced quadratically by days and by interactions of days with GADG. At 45 d in the feedlot steers from both diets produced 75% Choice carcasses with an average grade approaching low Choice. The remaining 25% graded Select. There was no improvement in the percentage of Choice carcasses for the remainder of the trial. Longissimus area tends to reflect muscle tissue growth of the steers as demonstrated by a positive relationship with carcass protein (R^2 = .46; data not shown). The raw data means for longissimus area suggest that little growth occurred after 45 d in the feedlot, especially for steers limit-fed grain during the growing phase. The same steers also gained very little carcass weight (12 kg) when the group slaughtered at 75 d was compared to that slaughtered at 105 d (Table 5). At 75 d, the steers selected for slaughter were 12 kg heavier than those left for slaughter at 105 d, but the difference was not significant ($P > .10$). The longissimus area of steers fed grain was larger than that of steers fed silage until the final slaughter. The equation for longissimus area contains a negative coefficient for the linear effect of days on feed and positive for the quadratic effect, a contrast to apparent trends indicated by the means. Close examination of the model revealed that the interaction of GADG and days on feed (linear and quadratic) caused the apparent discrepancy. Removal of the interaction terms yielded the following equation with a residual SD of 6.04:

$$\text{Grain diet: Longissimus area} = 59.4 - 12.0 \times \text{GADG} + .190 \times \text{DAYS} - .0011 \times \text{DAYS}^2.$$

$$\text{Silage diet: Longissimus area} = 54.3 - 12.0 \times \text{GADG} + .257 \times \text{DAYS} - .0011 \times \text{DAYS}^2.$$

Carcass protein gains, obtained by the product of carcass weight and percentage of fat-free organic matter (Coleman et al., 1995), followed a similar trend.

It seems that growth when manifested by carcass weight, backfat, and longissimus muscle was essentially complete by 45 d on feed (75 d for backfat) for steers fed grain during the growing phase. However, steers fed silage during growth entered the feedlot lighter and leaner (Coleman et al., 1995) and were still growing at 105 d. Previous data from this laboratory (Coleman et al., 1993) also suggested that if a significant part of growth occurred during a growing phase, carcasses were larger and leaner than those from steers fed ad libitum grain diets from a younger age or smaller size. We interpret the current data to suggest that steers limit-fed grain were much closer to finish at the end of the growing phase and exhibited lower dry matter intake and EB gains during finishing than steers fed silage (Table 4).

Meat quality, defined by beef flavor intensity, lack of connective tissue, and tenderness determined by Warner-Bratzler shear, was higher in meat from steers fed grain at the end of the growing phase, even after adjustment for rate of gain. Scatter plots (not shown) indicated no influence of rate of gain or EB weight on meat quality. Therefore, the difference due to diet apparently was independent of weight and rate of gain. Although the intercept for measurements including the ease of fragmentation and sensory panel tenderness score were not significant, raw means tended to differ at d 0 and 45 d on feed. Approximately 100 d on feed were required to overcome the diet differences. The tenderness data at 75 d are confusing; steers previously fed grain produced steaks that were less tender than on other dates. We attribute this to some unknown environmental event. In general, meat from steers fed grain was as tender at d 0 as after 105 d in the feedlot; steers fed silage was tougher at the start and changed only after steers had been on feed more than 75 d. The interaction of diet and days on feed for flavor intensity and shear force reflect similar changes.

Results are in agreement with most of the published literature comparing forage with grain diets; forage finishing often fails to produce sufficient intramuscular fat to attain more desirable marbling scores (Schroeder et al., 1980), although few studies have examined sensory attributes. However, most experiments involved feeding for ad libitum intake and thereby steers had faster rates of gain when fed grain. Therefore, source of energy could not be separated from level of net energy intake. Our data suggest that differences in tenderness or flavor intensity were due to diet alone, not to rate of gain. Further, these differences did not diminish until after 80 d of feeding a grain diet. Smith et al. (1977) noted that palatability of steaks was lower for steers slaughtered directly off grass, but the difference disappeared by 49 d on feed. However, they reported that effects of feeding regimen on sensory traits were unimportant when adjusted to either constant weight or longissimus muscle fat, but Warner-Bratzler shear values remained higher for grass-finished steers directly off grass and after 49 d on feed. The current results, along with those of Smith et al. (1977), indicate that shear force was sensitive to diet effects. Bruce et al. (1991) backgrounded Charolais steers on alfalfa/grass silage or corn silage and soybean meal for 124 d before a 51-d finishing period. Shear force was higher for steaks taken from steers fed alfalfa silage at the end of the growing phase. After 51 d on feed, tenderness of steaks from steers fed alfalfa had improved and, although not significantly different from tenderness of steaks from those fed corn silage, a difference of 1 kg of force remained. In the current study, difference between steaks from steers fed silage or limited grain was 1.78 kg at the end of the growing phase and 1.27 kg after 45 d on feed. Dockerty et al. (1973) found little difference in perceived tenderness of steers fed a corn diet or a corn cob-based low-energy diet at constant body weights of 341 and 454 kg.

However, steers held at maintenance for 6 mo had less backfat over the loin and lower yield grade. Also, Shaake et al. (1994) reported steaks from steers finished in a drylot were no more tender than those finished on summer pasture following fescue-clover backgrounding but were more tender than those slaughtered directly off fescue clover.

Our data suggest that even though a high percentage of Angus steers will produce a carcass quality grade of Choice after a relative short feedlot period, more time may be required to achieve acceptable tenderness. Marbling score is the predominant factor in USDA carcass quality grade. Parrett et al. (1985), Jones and Tatum (1994), and many others have shown only small but usually significant negative correlations between marbling score and shear force. Parrett et al. (1985) also found that days on feed produced similar correlations with tenderness and overall acceptability.

Implications

With moderate-framed Angus cattle, Choice carcasses can be produced after only 45 d in the feedlot following a growing period of 150 d at .6 kg/d. However, meat tenderness and other meat quality attributes remained inferior for steers grown on forage vs steers limit-fed grain-based diets. These differences diminished with a longer duration of finishing.

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